Ex. Doc. No. 21.

HOUSE OF REPRESENTATIVES.

ELECTRO-MAGNETIC TELEGRAPH—ASTRONOMICAL OBSERVATIONS.

LETTER

FROM THE

SECRETARY OF THE TREASURY,

TRANSMITTING

A report of the Superintendent of the Coast Survey, relative to local differences of longitude and astronomical observations generally.

JANUARY 6, 1849.

Laid upon the table, and ordered to be printed, together with 1,000 extra copies, 250 of which for the Superintendent of the Coast Survey.

Letter of the Secretary of the Treasury, communicating a report by the Superintendent of the Coast Survey, on an application of the galvanic circuit to an astronominal clock and telegraph register in determining local differences of longitude, and in astronomical observations generally.

TREASURY DEPARTMENT,
January 3, 1849.

SIR: I have the honor to transmit for the information of the House of Representatives a report from the Superintendent of the Coast Survey, Professor A. D. Bache, communicating the report of the assistant charged with telegraph operations for longitude, on an application of the galvanic circuit in connexion with an astronominal clock and telegraph register, to determining and registering the instant of the occurrence of any astronomical phenomena. As this application is of importance not only in the coast survey operations, but to practical astronomy generally, I have deemed it best to make special report of it to the House of Representatives, that it may thus obtain due publicity.

Very respectfully, your obedient servant,

R. J. WALKER,
Secretary of the Treasury.

To the Hon. R. C. WINTHROP,
Speaker of the House of Representatives.

COAST SURVEY OFFICE,
Washington, December 26, 1848.

SIR: I have received from Sears C. Walker, esq., assistant in the coast survey, who has been charged, under my direction, with the telegraph operations for difference of longitude, a report containing facts and suggestions which I deem of sufficient importance to present to you without further delay. They have grown out of the application of the electro-magnetic telegraph to the determination of differences of longitude in the coast survey, and relate to the use of a galvanic circuit connected with an astronomical clock and telegraph register, in producing a permanent record of regular intervals of time, and of any particular interval which it is desired to note. Mr. Walker proposes to abandon the method now in use of determining the times of occurrence of celestial phenomena, and to substitute the registering by galvanic means, which he shows has the advantage in accuracy, minuteness and rapidity. The number of observations which can be made in a given period is many times increased, and the record of the observations is permanent. A transit instrument, used according to Mr. Walker's plan, would furnish in one night the results usually attainable only in several nights. I have received from Dr. Locke, of Cincinnati, specimens of recording by his electro-magnetic clock which entirely fulfil all the conditions required by the astronomer.

When the first discoveries in electro-magnetism were made, it might have been pronounced at most improbable that practical astronomy would benefit by their development. The application now described by Mr. Walker is a new instance of mutual relations between branches of science apparently entirely unconnected. As it is highly interesting in a scientific point of view, so it will, I am convinced, be found most important to practical astronomy.

Very respectfully, yours,

A. D. BACHE,
Superintendent U. S. Coast Survey.

Hon. R. J. WALKER,
Secretary of the Treasury.

WASHINGTON, D. C., *December* 15, 1848.

DEAR SIR: I beg to call your attention to the importance of the use of an electro-magnetic circuit and an astronomical clock in connexion with Morse's telegraph register for the operations of the coast survey, and the general purposes of practical astronomy. Your thoughts having been first turned to the subject of the use of Morse's electro-magnetic telegraph in the longitude operations of the Coast Survey, in December, 1844, special instructions were issued to me in the autumn of 1845. Under these and subsequent instructions, the operations of 1846, '47 and '48, entrusted to my care, have, until near the close of the latter year, been conducted without the use of the *automatic clock register*.

The importance of the latter instrument induced you to direct the necessary researches to be instituted, for the purpose of introducing it into use in the Coast Survey service. Several methods have been suggested by eminent mechanicians and electro-magnetists. That of Mr. Wheatstone is briefly alluded to in the proceedings of the Royal Astronomical Society, for 1841, November 19th. The galvanic circuit in his clock, is made and broken by the use of a circular metallic disk, put on to the arbor of the seconds' hand. Alternate intervals of a second, or one sixtieth of the circumference, are made of a non-conducting substance. The disk is insulated and connected with one pole of a galvanic battery. A delicate spring connected with the other pole presses gently on this disk. Thus the circuit is made and broken at alternate seconds. This mode enables the primitive clock to control the motion of any number of clocks in connexion with it. Every time the circuit is broken or made, any receiving clock-wheel with sixty teeth may be made to advance one second, and this wheel may in the usual way control the minute and hour wheel.

Mr. Steinheil's galvanic clock is described in Schumacher's astronomical annual, for 1844. The particular machinery for making and breaking the galvanic circuit does not appear to be described; the general object is similar to Mr. Wheatstone's

I find, as yet, no account of the actual application of these electro-magnetic circuits and astronomical clocks to the purpose of permanently registering the current of time on the running fillet of paper, as used in Morse's electro-magnetic telegraph. It is, however, this latter combination that we must employ in our telegraph operations for longitude. The experience of its advantages for that purpose, induces me, also, to recommend it for the general objects of practical astronomy, as far as relates to the record of minute subdivisions of time, such, for instance, as the determination of absolute or relative right ascensions of the heavenly bodies, or of the local time of their culmination.

The process to be used is dependent on two distinct contrivances. The first is to cause the most delicate astronomical clock to make and break the galvanic circuit at uniform intervals, (say of a second of time,) by an apparatus that cannot possibly injure its machinery or its rate of performance, when connected with the current of the most powerful battery. That of Mr. Wheatstone, and I presume of Mr. Steinheil accomplishes this purpose effectually.

Professor Bond, without having seen any notice of Wheatstone's invention, had proposed to make the mechanical contact and separation of the pallet and teeth of the escapement wheel, the closing and breaking of the circuit. This method may be readily applied to insulated portions of these parts. It will certainly succeed in in practice. It is, however, liable to the danger of deflagration of the metalic surface of contact, and perhaps to that of modifying the arc of vibration, by electric or electro-magnetic repulsion.

Dr. Locke of Cincinnati, to whom I mentioned your wishes on the 25th of October, not having seen a description of Mr. Wheatstone's electro-magnetic clock, undertook to make a series of experiments on the subject. He succeeded, on the 6th of November, in inventing a method which, like the former, is found to be perfectly successful in practice, and free from danger to the machinery and motion of the clock. Instead of a disk, Dr. Locke uses a wheel with sixty teeth, each of which when horizontal strikes against the handle of a platinum tilt hammer, weighing about two grains, and knocks up the hammer, which instantly falls to a state of rest on a bed of platinum. The fulcrum of the tilt hammer and the platinum bed rest severally on a small block of wood. Each is connected with a pole of the galvanic circuit, and the circuit is alternatively broken and made by the rising and falling of the hammer. The latter operation takes about one-tenth of a second of time.

I think it is manifest that either method will succeed in practice, which alone can test their relative excellence. To Mr. Wheatstone, however, belongs the merit of priority in effecting the primary object of causing the astronomical clock to make and break the circuit of a galvanic battery, without injury to the machinery or movement of the clock.

Waiving the question of the relative excellence of the two inventions, and leaving it as a subject for special experiments, I come now to the second requisite for the fullfilment of your wishes, viz: the connexion of the astronomical clock with Morse's electro-magnetic telegraph. In this department, so far as I am informed, the first experiment has been made in this country.

An experiment of the combination of an electro-magnetic clock and Morse's telegraph register, was made by Professor Mitchell and myself at the Cincinnati observatory on the 26th of October last, on a plan, however, which I did not consider to be suitable for nice astronomical observations.

On the 17th of November last, Dr. Locke's delicate astronomical clock, of his own construction, was supplied with the requisite apparatus made from his drawings by his son. At the expense of the coast survey, I directed wires to be put up for the purpose of connecting his clock with the Cincinnati and Pittsburg line, about four hundred miles in length. The experiment was eminently successful, and the registering of the seconds of time on the running fillet of paper was continued for two hours at all the offices along the line, much to the astonishment of the operators. I send you a specimen of the graduated fillet of paper. It consists, as you will notice, of an indented line of about nine-tenths of an inch in length, followed by a complementary blank space of about one-tenth. The two make a second of time, commencing with the beginning of the line.

This graduated fillet of paper I will call for the present the *automatic clock register*, whether it is furnished by Wheatstone's or Locke's apparatus for attachment to the arbor of the seconds hand of the primitive clock.

In order to carry out fully your wishes and instructions, it would be necessary that this automatic clock register should distinguish the hours, minutes and seconds. Doctor Locke proposes for this purpose to make the beginning of the ordinary minutes omit *one*, of *fives* of minutes *two*, of *tens* of minutes *three*, and of *an hour* omit *four* consecutive blank spaces. Thus *ordinary* beginnings of minutes have continuous lines of *two* seconds, *fives three*, *tens four*, and *hours five*.

The mode of using the register for marking the date of any event that cannot be determined *automatically*, but whose occurrence must be known from human sensations, is to tap on a *break circuit key* simultaneously with the event. The beginning of the short blank space thus registered in the midst of the indented line of the *automatic clock register*, fixes, by a permanent printed record, the date of the event, or rather the date of the human estimate of the event, as indicated by the tap of the key.

For this mode of distinguishing the hours, minutes and seconds on the fillet of paper, and for the idea of using the break circuit key, I was indebted to Doctor Locke. This kind of key is required by the necessity of having a closed circuit for the *register* as much of the time as possible, so that an event occurring any where along the line may be instantly recorded on the register.

Having thus given credit to Mr. Wheatstone and to Doctor Locke for the parts severally performed by them in the perfection of this process, I beg to suggest the following slight modification of Doctor Locke's mode of marking seconds, whether we use for our automaton Wheatstone's circular disk or Locke's toothed wheel and platinum tilt hammer. I would mark the beginnings of ordinary, fives and tens of minutes and hours, as Doctor Locke does. I would make the blank spaces of the other ordinary seconds the smallest possible consistent with the certainty of breaking circuit. The blank spaces of the *fives* of seconds should be visibly larger, those of *tens* still larger, finally those of *thirties*, largest of all.

By this arrangement the eye would readily distinguish the exact value of the numbers of whole seconds. An inch of paper is, I think, enough for a second of time. The probable error of the reading of the fractions of a second with a proportional scale or compass, will not be greater than one hundreth of a second. I would have the register adjusted by a centrifugal clock like those of the Munich equatoreals, so as to deliver, as near as may be, one hundred inches of paper in one hundred seconds of time of the *automaton clock register*.

Instead of a proportional compass we may use a graduated scale of some translucent substance laid on the printed register. For the sake of uniformity of hygrometric expansion, a graduated scale made of a portion of the registering fillet will perhaps be preferable. A small correction may in this case be applied if necessary, for the rate of the automatic clock on an assumed scale of paper of a second to an inch. A relative rate of two seconds per minute (an improbable occurrence) will on the average cause only an error of one hundreth of a second in reading off by the scale.

All that I have now proposed may be accomplished by the first disk or toothed wheel and tilt hammer.

Dr. Locke's mode of distinguishing the subdivisions of minutes appears to be satisfactory. I see no reason why it may not be effected by a toothed wheel on the arbor of the minute-hand, and another on that of the hour-hand. I mention this for the sake of simplicity, leaving to the mechanician his choice of the mode of effecting the purpose.

In printing on this *automatic clock register*, the dates of such events as a series of bisections of a star by the successive wires of a transit instrument placed at equatorial intervals of two seconds or more, short blank spaces may be made by dwelling for a very small time with the finger on the *break circuit key*.

Isolated events, like the phases of an eclipse or of an occultation, may be distinguished by dwelling with the finger on the key for a space of time longer than the maximum of blank space used in distinguishing the thirty seconds.

In this way we cannot fail of imprinting the date of an event. If the signal break circuit tap occurs in the midst of one of the small blanks, this precaution will secure the record, with an average liability to error for such rare instances, of only one-fourth of the actual blank space of the *automatic clock register*.

Yours respectfully,

SEARS C. WALKER,
Assistant U. S. C. S.

To Professor A. D. BACHE, L. L. D.,
Superintendent U. S. Coast Survey.

COAST SURVEY OFFICE,
Washington, D. C., Dec. 15, 1848.

DEAR SIR: Having, in the first part of this special report, given a brief history of the steps that led to the invention of the automatic telegraph clock, and of its application to Morse's electro-magnetic telegraph, I beg to offer you such suggestions as have occurred to me in relation to the practical application of it to the longitude operations of the coast survey, and to the general purposes of practical astronomy, on which the survey is dependent for the accuracy of its work.

The great importance of an automatic telegraph clock has often been the subject of conversation between us, but your chief efforts were, necessarily, directed at first to the means of procuring it. A hasty glance at the advantages that would result from the certain possession of such an instrument was made by Dr. Locke and myself, on the evening of the 17th of November, while watching its performance for a term of two hours or more. Having reflected much since, and consulted with my friends both in and out of the coast survey, I am more and more convinced that it is difficult to form an over estimate of its importance in every department of practical astronomy that involves the nice determination of absolute dates, or of their relative intervals in time. Throughout the whole range of practical astronomy, epochs of time and their relative intervals have been hitherto measured by astronomers by listening to the beats of a clock or chronometer, and estimating the fraction of a second between them when any event has occurred, such as a phase of an eclipse, an occultation of a star, or a bisection of a star, comet, or planet's centre or limb, by the wires of a transit instrument. This use of the ear has been a matter of necessity, not of choice. It is, in every respect, in the subdivisions of time and space, a very imperfect organ. While the eye readily estimates the proportional parts of a line with the precision of a tenth, the ear seldom distinguishes smaller portions of an interval of time than a fifth.

In the case of observing transits of a star with a seconds clock, when greater precision than the estimate of a fifth of a second is required, it is only obtained by long practice and experience, and by the use of an *ocular* estimate of portions of space where the star *was* at the time of bisection, and where it was *seen* to be at the time when the two beats immediately preceding and following this bisection were *heard*.

In order to increase the precision of the comparison of two sounds together, in point of time, it is necessary gradually to diminish their interval asunder until the *minimum audible* of about a hundredth of a second is attained. This advantage attends the comparison of chronometers by coincidence of beats, when one has a more rapid movement than the other; but it cannot be brought to bear upon the association of the time of a visible bisection of a star with the date of the hearing of the beats of a clock. The average uncertainty of such an association, as appears from my last report of the result of four thousand experiments on this subject, among the officers of the coast survey, is seventeen hundredths of a second. Of this sum, the greater portion is probably due to the imperfection of the ear as an organ, in associating its sensations with those of sight. I do not speak now from actual experiment, as I hope to do another year. It is well known, however, that the nerves and sensations of sight and touch are far more intimately connected together than those of the eye and ear.

I have repeatedly noticed the advantage of the substitution of the sense of touch for that of hearing in the use of *chronographs* for making a visible register of the dates of bisection of transit wires by a star. I have known persons afflicted with deafness, and, from that circumstance, compelled to resort to the use of chronographs, to make more precise observations than those of persons in other respects similarly situated; but who, having good sight and hearing, estimated fractions of a second by means of the use of the eye and ear. I think we may assume, subject, however, to correction by actual experiment, that the precision of the combinations of sight and touch is to that of sight and hearing nearly as seventeen to ten.

This estimate supposes that no error is committed in the mechanical operation of imprinting and reading off.

Now, this certainty is furnished for the first time in the history of the science by the use of the automatic telegraph clock. The objection to the use of chronographs in an observatory has arisen from the uncertainty of their rates, and from the necessity of immediately transcribing and obliterating the record made on them for the purpose of indentifying it, and preparing the dial for a fresh record. Both of these objections are removed by the use of the *automatic clock register*.

The *rate* of this register has all the precision known to astronomers. The length of a continuous fillet is limited only by the size of the paper reels that may be considered convenient for use. An eight-day clock might be made to deliver a continuous graduated register from one winding to another.

A single label on any part of it, to identify one of the seconds, fixes them all.

I have before remarked that the error in the mechanical part of imprinting a date on the *automatic clock register*, and in reading off, need not exceed a hundredth part of a second. It may, in fact, be reduced to a ten-thousandth part of a second by substituting for the paper fillet a metallic cylinder revolving like a barrel organ, and graduating the seconds on a spiral line. Perhaps Mr. Bains's method of registering on a paper, in a spiral line, may supersede Mr. Morse's running fillet.

The great advantage of the method of imprinting the dates of bisections of a star, by the wires of a transit instrument, does not depend merely on the increase of the precision of a single result.

The facility of acquiring the practical skill necessary for tapping on a key, at the date of a visible bisection, is very great. A few hours in this respect take the place of months, if not of years, spent in learning to associate together the sensations of sight and hearing, so as to make a good transit observation.

The third and paramount advantage of the method of imprinting the dates of bisections of wires by a star, is in the *sevenfold* accumulation of results in a single culmination, or in a given period of time.

Fifteen seconds is the ordinary equatorial interval for the wires of a transit instrument, and we have the authority of the greatest of practical astronomers, the lamented Bessel, that five wires, with this interval, are better than seven wires, compressed into the same space.

By using the method of imprinting the dates of the bisections of these wires, on the *automatic clock register*, where the use of the ear, and the counting of beats, and the manual labor of writing down these dates, are all dispensed with, the equatorial intervals may be reduced from fifteen to two seconds, or even to one and a half.

In this manner the number of bisections in a single culmination of a star may be mutiplied *sevenfold*, as I have already mentioned.

The advantage of the method of imprinting dates of bisections of wires by a star on the *automatic clock register*, from those three seperate sources of gain, may in round numbers, be estimated at *tenfold.*

The remarks that follow are based on such an estimate, and are consequently subject to a proportional modification, when the true numerical ratio shall have been determined by experiment. According to this estimate then, we are authorized to conclude, THAT THE VALUE OF A NIGHT'S WORK WITH A TRANSIT INSTRUMENT, BY THE PRINTING METHOD, IS ABOUT TEN TIMES AS GREAT AS BY THE METHOD NOW IN USE AMONG ASTRONOMERS.

For moon culminations, which depend upon the comparisons of transits of the same heavenly bodies, here and in Europe, *fifty* wires may take the place of *seven*, and one *month's* work may take the place of a year's work in the manner hitherto performed.

For catalogues of stars, such as were formerly made in Paris and Konigsburg, and are now made at Munich, Bonn and Washington, where a transit over one wire only, is usually observed in a night, *seven* transits may now take the place of *one*, and from the superior facility which the printing method gives of adjusting the transit instrument, the subject of the right ascension of the stars of such catalogues may now be exhausted for the epoch of the observation.

In the case of the *ten year* catalogues of the right ascension of stars, from the royal observatory at Greenwich, the same labor spent by the astronomer at the transit instrument, by the use of the printing method, may furnish one of equal precision *every year*.

I am bound to make an exception in favor of the catalogues of stars furnished by Mr. Rumker from the Hamburg observatory. This indefatigable astronomer, by some process apparently unknown to his professional brethren, has already doubled the ordinary number of bisections of a star at a single culmination.

In his catalogues of right ascensions of stars the use of the printing method would only introduce a *five-fold* instead of a *ten-fold* gain.

I venture to suggest that our national expedition to Chili, under Lieutenant Gilliss, will, by the use of the printing method, furnish nearly *ten* times the precision in the value of the parallax of Mars, from his relative transits with the same star, both east and west of the meridian, that would result from the ordinary method of observation.

There is, however, no one branch of practical astronomy, or coast survey operations, where the benefit of the *automatic clock register* will be so great as in the determinations of relative longitude of the stations.

One night's work with the printing method will be worth as much as any single campaign has been heretofore between any two stations.

The importance of this branch of the duties of the coast survey induces me to dwell more at length on the subject. Your operations propose, for the first time in the history of geodesy, to measure astronomically a long arc of a parallel with a precision commensurate with the former and present astronomical measures of arcs of the meridian.

I would, for this purpose, respectfully recommend the mounting of one of Mr. Wheatstone's, or of Dr. Locke's, clocks at some central astronomical station, having easy telegraphic communication with the northern and southern points of the coast survey. This central station, and any other one or more stations intended to be compared together, may be supplied with transit instruments, constructed with special reference to the advantages of the printing method. I would respectfully recommend the use of a transit instrument with a frame of a cast iron box, and with three or more doubled faced levels on each side suited to both zenith and nadir pointings. When not too cumbersome, as in the case of the coast survey instruments, I would wish for an azimuth adjustment, with graduated micrometer head, like the Simms transit instruments now in use in the coast survey. I would wish to retain the principle of rapid reversals, and would extend it to zenith stars. The inner portion of the pivots may rest on counterpoises with friction rollers. I would wish the reversing apparatus to have the following advantages, leaving to the mechanician the decision as to the mode of securing them. The time occupied in the reversal and in repointing the instrument, by making it revolve on its axis through the double of its zenith distance before reversal, should not exceed twenty seconds. The pointing may be done by means of an adjustable clamp, suited to the declination of the star. The pivots need not be elevated more than half an inch in order to move free of the sockets. Two turns of a screw might elevate; one turn more reverse it, and two more turns place it at rest on the socket and friction rollers.

The net work of the transit instrument may consist of groups of five wires, each separated by an interval of once and a half the ordinary space.

For the sake of rapid observation of circum-polar stars, the inner group may have half the ordinary interval. In the case of equatorial stars, only three of these wires need be used. The equatorial intervals may be one for the inner, and two seconds for the other groups. The intervals between the groups may be three seconds. My micrometric measures, with the great Fraunhofer equatorials, show that fifteen hundredths is an ordinary, and two-tenths of a second of time an extreme value of the subtense of a spider line for a four foot tube. The smallest clear intervals between the wires would be *four*, the ordinary *nine*, and the greatest *fourteen*, diameters of the opake wires.

The number of these tallies may be seven, nine, or eleven, according to the focal length of the telescope, and the mechanical facility of graduating the diaphragm and of setting the spider lines. Since the register is permanent, and may remain for reference, it is only necessary to enter in the written journal the mean for each talley from the mean of the five readings. To prevent the accumulation of these registers from filling too much space, the same fillet of paper may have several parallel lines of the *automatic clock registers* imprinted on it, by means of a micrometer motion of the graver.

Where the observatory is fixed, and the line short, and the Grove's cups are charged anew with acid every day, the registering fillet may contain one or two months' continuous record on one reel. All the transits observed in the occupancy of a single temporary station may be preserved on one reel. In order to identify dates, and particularize records, the observer keeps a memorandum book in which he records the level readings, and refers to each celestial object by a letter or number, with accents or side numbers denoting the order of the lines on the fillet.

A duplicate mark is made on the fillet itself. A receiving reel of dimensions similar to the delivering one affords a compact disposition of the printed register. A tell-tale check connected with it will enable the transcribing clerk to turn at once to any date on the paper, without examining the intermediate spaces.

In using these instruments for longitude operations, zenith stars are selected at the eastern station. The declination clamp is adjusted ready for reversals.

The levels are all read. Twenty dates of bisections in the first position of the instrument are imprinted, the reversal and re-pointing is effected, twenty more bisections by the same wires in a reversed position of the instrument are imprinted, the levels are again read, and the registering fillet labeled. The same operation is repeated on the same star at the western station. The electro-magnetic clock may be rated at the central station. The *automatic register* may be kept there, and the printed record may be there preserved. Check registers may be kept at the other stations. The imprinted culminations of two fundamental stars at the same station, whether eastern, or western, or central, will serve to fix the rate of the primitive clock. The reversals remove the error of collimation, and furnish, by taking the means of the printed dates for each wire, twenty normal bisections with reference to the optical axis of the telescope. On applying the corrections for the levels, we have twelve normal level readings with reference to the zenith and consequent meridional point near the position of actual observation. The facility of observing transits of circumpolar stars, gives extraordinary precision to the azimuth correction which moreover nearly vanishes with circumzenith stars.

A consideration of these numerous advantages of the printing method for longitudes of stations, leads me to believe that one single culmination of a circumzenith star at each of the two stations thus observed may give their relative longitudes to a few hundredths of a second, which is all that can be said of our present knowledge of those of the Greenwich and Paris observatories, the two oldest in the world. The check readings of the levels with nadir pointings adds to the certainty of the work. If the concluded difference of longitudes of the zenith and nadir portions of the meridians conform, our confidence in the result is much strengthened.

If the discrepancy is sensible, the mean of the results may serve to eliminate any want of symmetry in the pivots or sockets or any irregular action of gravity or sudden change of temperature on the parts of the instrument.

In the above process all sources of error in the result are eliminated except the difference of the *break circuit armature* times, and personal equations of the astronomers in tapping on the key. The rule adopted in good telegraphic offices, and which must be inflexibly adhered to in all astronomical operations, of adjusting the *outer* and *inner* limits of *armature distance* to a *minimum* value, secures us against error from the first source. When the total quantities are so small as to be insensible to the ear, their difference, which is a term of the second order, must necessarily be evanescent.

The personal equations of tapping on the key for the instant of a bisection are much smaller than those which arise from the combination of sight and hearing.

They are also more uniform and less dependant upon the nervous temperament of the individuals. They may be determined in a few minutes' time by the astronomers, on meeting at the same station by striking alternate wires, each party being alternately a leader. A few pairs of culminations printed in this way fixes the value of the equation if any exist.

These views, which I have felt it my duty to lay before you at length, are the result of a separate trial of each of the processes involved in the art of imprinting dates. The experience of the last summer furnishes some six hundred cases of imprinting dates on an ungraduated fillet of paper. Dr. Locke's electro-magnetic clock, on the 17th of November, furnished an ample trial of the method of *graduating* the paper.

The combination of the two operations so as to imprint the dates of culminations on the *automatic clock register*, would have been tried that night, but for the failure of the line from Pittsburg to Philadelphia. The full trial, however, of the combination in all its perfection, requires the construction of the proper instruments; with them, under your instructions, I hope, at an early date, to submit these opinions to the test of practical experiment.

Permit me to say a word on the experience of the Coast Survey in regard to the length of telegraph lines. This year we made abundant experiments on the line from Philadelphia to Louisville, a distance in the *air* of *nine* hundred miles, and in circuit of *eighteen* hundred miles. The performance of this long line was better than that of any of the shorter lines has hitherto been.

Not more than two or three good astronomical nights, at Cincinnati and Philadelphia, were lost by failure of any part of the line, in the period of two months nearly of our stay at Cincinnati. I learn from an authentic source that the same success attends the work from Philadelphia to St. Louis, A DISTANCE OF CIRCUIT OF ONE-TWELFTH OF THE EARTH'S CIRCUMFERENCE.

The number of Grove's pint cups used is about one for every twenty miles. It is natural to conclude from this experiment, that if a telegraph line round the earth were practicable, *twelve hundred* Grove's pint cups, in equi-distant groups of fifties, would suffice for the galvanic power for the whole line.

The daily expense of acids for maintaining this motive power, would be about five mills per day for each cup, or six dollars per day for the whole line.

Yours, respectfully,

SEARS C. WALKER,

Assistant U. S. C. S.

To Professor A. D. Bache, L. L. D.,

Supt. U. S. Coast Survey.